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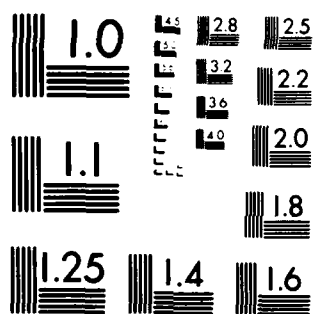   DEVELOPMENT CENTER SAN DIEGO CA G W LEWIS NOV 83
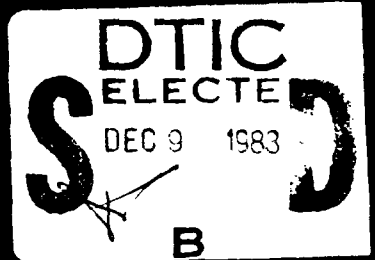UNCLASSIFIED   NPRDC-TR-84-3   F/G 5/10   NL

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BIOELECTRIC PREDICTORS OF PERSONNEL PERFORMANCE: A REVIEW OF RELEVANT RESEARCH AT THE NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER

Gregory W. Lewis

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R. E. Blanchard

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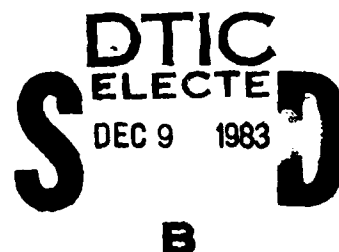| 4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
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Military personnel assessment has primarily depended on paper-and-pencil tests. Such tests predict academic performance but have been criticized for their ineffectiveness in predicting on-job performance. Results of recent research on brain function, which emphasizes "process" rather than "content," suggest that certain brain wave tests predict on-job performance better than do the traditional tests. One area of this research includes bioelectric potentials. This report summarizes NAVPERSRANDCEN research in the area of bioelectric potentials (brain event-related potentials (ERPs)) and

their possible applications toward improving personnel selection, classification, and predicting on-job performance. These potentials are recorded from scalp electrodes in response to sensory input such as flashes or clicks.

Research results show that ERPs are related to success in remedial reading, aptitute test scores, performance in fighter aircraft and on a sonar simulator, and to promotions and attrition. They suggest that ERP data are better able to discriminate and classify performance groups than paper and pencil test scores.

FOREWORD

This research and development was conducted within task areas ZR042.04 and ZF61512001, work units 042.04.03.02 (Measures of Averaged Evoked Cortical Potential as Possible Predictors of Learning Potential and Performance) and 512.001.03.01 (Evaluation of Psychobiological Methods in the Screening and Selection of Naval Personnel) under the sponsorship of the Director of Navy Laboratories.

This report summarizes research conducted at the Navy Personnel Research and Development Center in the area of bioelectric potentials. Earlier efforts in this area, which were funded under the Independent Research and Independent Exploratory Development Work Units mentioned above, were described in NPRDC TR 77-13, TN 77-7, TR 79-13, and TR 80-26. Research relating biotechnology predictors to potential applications in Navy training was conducted within task area ZF63-522.001, work unit 522.010.03.06 (Evaluating Evoked Potentials for Adaptive Instruction) and was described in NPRDC TRs 82-8, 83-11, and 83-16.

The primary objective of current research in this area, which is being sponsored by the Defense Nuclear Agency, is to determine the feasibility of using biotechnology measures such the brain event-related potential to improve physical security personnel performance reliability. NPRDC TN 83-9 provided a review of the stress literature related to performance. Subsequent reports will describe experimental procedures for assessing performance under stress and cerebral potential measures related to stress.

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Commanding Officer

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SUMMARY

Problem and Background

Assessment of personnel has depended heavily on paper-and-pencil tests. Although such tests are able to predict academic and training performance, they are only marginally effective in predicting on-job performance. Results of recent research on brain functions, which emphasizes "process" rather than "content" variables, suggest that certain brain wave tests predict on-job performance better than do the traditional tests. One method of assessing brain processing is by analyzing brain wave activity such as the brain event-related potential (ERP). ERP records are very small electrical signals (microvolt, μV) obtained by computer analysis of the brain's response to sensory simulation. At least two types of brain processing have been suggested--sequential and simultaneous--and may be assessed by ERP techniques.

Objective

The objective of this report is to summarize research conducted by the Navy Personnel Research and Development Center on ERPs and their possible application toward improving personnel assessment.

Approach

Brain wave data have been obtained from several personnel groups, including basic training recruits, aviators, and antisubmarine warfare trainees. Eight channels of ERP data were recorded for each subject from sponge-tipped scalp electrodes. Amplitude measures (i.e., root mean square, $\mu Vrms$) were computed for each of the eight waveforms.

Results

Research results have:

1. Shown relationships between (a) ERP predictor data and success or failure in a Navy remedial reading program, (b) sensory interaction, distractibility, and reading ability, and (c) visual ERP measures and Navy paper-and-pencil aptitude test scores.

2. Suggested methods of (a) assessing cognitive information processing to enhance training, (b) differentiating pilots and radar intercept officers (RIOs), and (c) relating ERP differences to performance with pilot and RIO groups.

3. Shown that ERPs are potentially useful in (a) predicting performance of antisubmarine warfare sonar operators and enlistees' promotions and attrition, and (b) the design and development of Navy display systems.

Future Research

This Center has established an extensive library of ERP predictor and performance follow-up data using data acquired from both in-house and operational environments. Research will continue to evaluate and validate existing and new technologies (e.g., biomagnetic recordings) for improved personnel assessment.

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LIST OF FIGURES

INTRODUCTION

Problem

The military services depend heavily on paper-and-pencil testing to evaluate personnel. Although results of such testing can be used to predict academic performance reasonably well, they are less effective in predicting on-job performance. Attempts to improve personnel assessment by developing additional paper-and-pencil tests have generally not proven to be successful. There is a need for new kinds of testing procedures that will supplement the information derived from paper-and-pencil tests and provide both the Navy and the individual with an improved understanding and more complete assessment of the unique compatibility of each individual.

Background

In 1975, the Navy Personnel Research and Development Center (NAVPERSRAND-CEN) established a research facility to investigate improved methods of predicting on-job performance. Advances in understanding brain processing, along with progress in the fields of electronics, computer science, and psychophysiology, suggested that procedures using brain wave measures would make feasible more accurate assessments of individual differences and unique capabilities.

It has been suggested that the brain has at least two different modes of cognitive processing: Verbal or analytic information processing has been associated with left-hemisphere (LH) activity in most right-handed individuals; and spatial or integrative processing, with right-hemisphere (RH) activity. These two modes of cognitive processing were initially suggested by studies of patients with brain lesions and, later, by studies of "split-brain" subjects. More recently, these processes have been assessed by measures of brain electrical activity, such as electroencephalographic (EEG) and brain event-related potential (ERP) records, which show brain activity as very small electrical signals (microvolts, μV) recorded from the scalp. The EEG shows ongoing activity, while the ERP shows activity after the brain has been stimulated (e.g., via light flashes or clicks to the ears). People performing verbal tasks often have decreased LH EEG/ERP amplitude; and those performing spatial tasks, decreased RH amplitude. Such decrease in EEG/ERP activity may be considered an index of increased information processing within a particular hemisphere. Some individuals may use predominately a verbal-analytic information processing style for learning, problem solving, and decision making; and others, a spatial-integrative cognitive style (Bogen, 1969; Galin & Ornstein, 1972; Dimond & Beaumont, 1974; Callaway, 1975; Galin & Ellis, 1975; Knights & Bakker, 1976; Ornstein, 1977; Kinsbourne, 1978).

However, investigators have indicated that caution should be used in relating EEG data to the lateralization of cognitive function (Gevins, Zeitlin, Doyle, Yingling, Schaffer, Callaway, & Yeager, 1979; Gevins, Doyle, Schaffer, Callaway, & Yeager, 1980; Gevins & Schaffer, 1980). Tasks such as Koh's block design (spatial) and sentence writing (logical) have often been used to assess lateralization of brain function for the RH and LH respectively. Gevins and his colleagues have suggested that the EEG asymmetries found by other investigators may have been due to motor movement, varying difficulty, and other uncontrolled nonmental aspects of the tasks. When the Gevins' group adhered to rigid criteria that reduced or removed nonmental aspects of the tasks, they were unable to obtain significant lateralization in their EEG records.

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It was initially thought that traditional paper-and-pencil aptitude tests could predict academic performance better than could on-job performance, because they primarily tap verbal, analytic LH processing. However, on-job performance may also require spatial or integrative RH processing. There have been many attempts to assess RH functioning by traditional testing procedures but with little success. Procedures like the ERP may not only tap RH processing to a greater degree than do the traditional paper-and-pencil tests but also predict on-job performance more accurately. Assessing individual differences with an emphasis on "process" rather than "content" variables, as suggested by the concept of brain activity, may prove more successful in assessing personnel and predicting human performance than the traditional tests.

Objective

The objective of this report is to describe briefly research conducted at NAVPERS-RANDCEN that relates bioelectric (ERP) data to several categories of performance.

METHOD

Procedure

All of the research projects employed similar data collection procedures. Each subject was briefed on the research procedures and purposes and, after he had signed voluntary consent forms, was prepared for recording. The technician cleansed the subject's hair and scalp at the electrode sites with an alcohol-impregnated cotton swab. A Lycra (elastic cloth) helmet was then placed on the subject's head. Recording electrodes were placed in contact with the scalp over eight predetermined sites (see Figure 1).

F3		F4	Frontal
C3	C_z	C4	Central
P3	P_z	P4	Parietal
O1		O2	Occipital
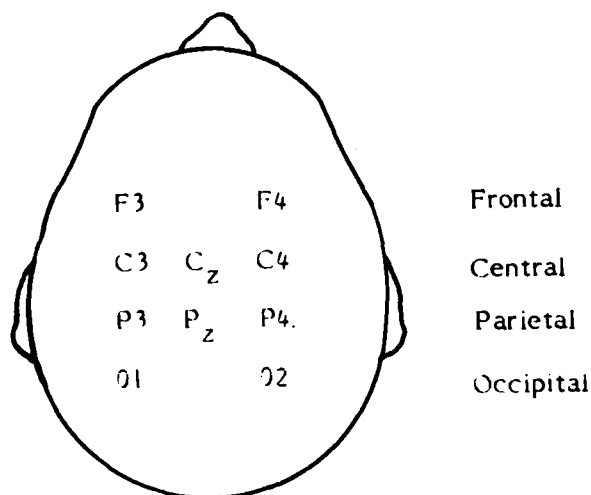
Figure 1. Electrode site montage.

Standard EEG recording electrodes (Beckman miniatures, 11mm) were attached to clear plastic extension tubes (38mm long) filled with sterilized electrolytic solution. A small sponge (microcell foam) soaked with the electrolyte held the solution in each tube and made contact with the electrode paste on the scalp. The extension tubes were placed into lucite holders that were attached to a Lycra (elastic) helmet. The electrodes were placed in the frontal (F3 and F4), central (C3 and C4), parietal (P3 and P4), and occipital

(O1 and O2) LH and RH regions (Jasper, 1958). They were referenced to the vertex (Cz), while the subject ground was at Pz. Slow potential drift, which otherwise would have been picked up at the recording site, was minimized by using the extension tubes. All electrodes could be attached in about 6-8 minutes with impedance readings about 2K ohms.

When the electrodes were in place and checked, the subject was instructed to observe his real-time EEG activity on the oscilloscope display. He was instructed to move his jaws and eyebrows so that he could observe how muscle artifacts may contaminate the visual ERP (VERP) data. He was then seated in a darkened room in alignment with the visual stimulus and given a hand-held switch that permitted him to suspend all stimulus presentation and analysis operations. He was instructed to press the switch to reject muscle artifacts when he had to move. Eye movement artifacts were detected and rejected automatically by the computer in several of the studies. ERP artifacts could be manually rejected at all times.

The visual stimulus was a commercial fluorescent tube mounted in a 7" x 15" box with a power supply triggered by a computer-generated pulse. The stimulus duration was approximately 2 msec, flashed aperiodically, every 1 to 3 seconds. Stimulus intensity was about 10 cd/m^2. Visual stimulus intensity for the on-site recording during the aviator study (Lewis, 1979; Lewis & Rimland, 1979) was about 165 cd/m^2. Since all subjects did not display well-defined ERP components, the traditional ERP component amplitude (μV) and latency (msec) measures proved inadequate. An integrated amplitude measure, the root mean square ($\mu Vrms$), was found to be an adequate measure.

The analog data were amplified, filtered, and then "averaged" in the laboratory computer to produce the ERP records. Figure 2 shows typical ERP data and calibrated amplitude values ($\mu Vrms$). The numbers displayed in Figure 2 are $\mu Vrms$ times 100; therefore, one must divide by 100 to obtain the correct amplitude value. The upper number at each site represents the $\mu Vrms$ value for the first 50 flashes; and the lower number, the second 50 flashes. The waveforms for each 50-flash series were superimposed on the same baseline.
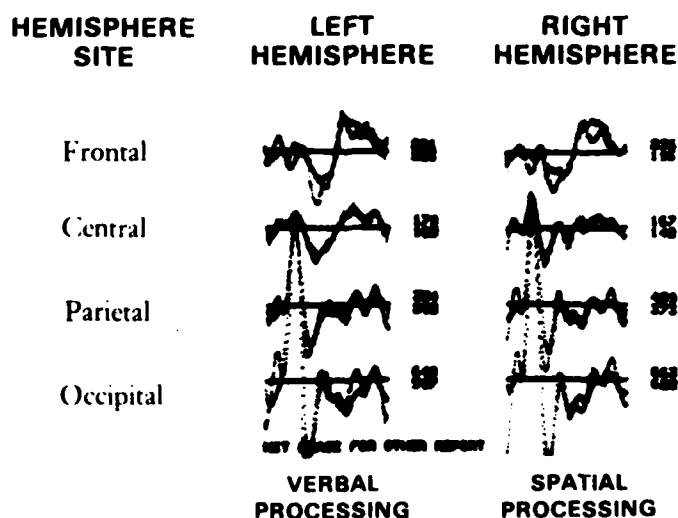

Figure 2. Sample visual ERP data amplitudes ($\mu Vrms$).

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Instrumentation

Data were obtained on a field-portable computer system for all research projects (Figure 3). The central processing unit (CPU) is a Data General NOVA 2/10 (32K memory) equipped with a three-drive floppy disc unit (Advanced Electronics Design, Inc., Model 2590), a small solid-state keyboard, a high-resolution oscilloscope monitor (Tektronix, Model 603), a custom-made power supply and fluorescent tube for visually stimulating the subject, and a custom-made multiplexed eight-channel EEG unit with band-pass set for 0.2-30Hz. Subject protection is provided through optical isolation and by placing the entire computer data acquisition system into a heavy duty ultra-isolation and medically calibrated (<10μA) transformer (Topaz, 2.5KVA). A color video terminal (Advanced Electronics Design, Inc., Model AED-512) has been added to this system for increased capability in presenting stimuli and displaying data. Video hardcopy (Tektronix, Model 4632) is also available. Frames do not suggest endorsement.

Figure 3.   Subject wearing electrode helmet seated in front of
computer system.

RESULTS

This section describes ERP projects performed at NAVPERSRANDCEN under the following two categories:

1. **ERP Measures and Academic Performance.** Results of research conducted under this category have (a) shown that ERP measures are related to success or failure in a Navy remedial reading program (Lewis, Rimland, & Callaway, 1976) and that VERP measures are related to Navy paper-and-pencil aptitude test scores (Lewis, Rimland, & Callaway, 1977), (b) suggested methods of assessing cognitive information processing to enhance training (Lewis, Federico, Froning, & Calder, 1981), and (c) shown that sensory interaction is related to reading ability (Lewis & Froning, 1981).

2. **ERP Measures and Job Performance.** Results of research conducted under this category showed that (a) VERP measures could be used to differentiate pilots from radar intercept officers (RIOs), (b) ERP asymmetry r·lationships were related to aviator performance (Lewis, 1979; Lewis & Rimland, 1979), (c) VERP measures were useful in predicting the performance of antisubmarine warfare (ASW) sonar operators (Lewis, Rimland, & Callaway, 1978; Lewis & Rimland, 1980), and (d) ERP measures may be relevant and applied to security guard personnel (Lewis, 1980, 1981).

ERP Measures and Academic Performance

ERP Measures and Success in a Remedial Reading Program

A large percentage of Navy recruits fail to complete their term of enlistment and are discharged prematurely; many of those who do complete their enlistment fail to meet the standards for reenlistment. Thus, Lewis, Rimland, and Callaway (1976) attempted to determine whether VERP measures could be used to identify recruits with a high risk of premature discharge. The subjects were 73 Caucasian males (average age--19 years) who had been assigned to the Academic Remedial Training (ART) Unit, Naval Training Center, San Diego, because they had scored between the 20th and 40th centiles on the Armed Forces Qualification Test (AFQT), a test of general aptitude, and between 3.0 and 5.5 grade levels on the Gates-MacGinitie Reading Test. Subjects were divided into two groups: The ACT group, comprised of the 32 recruits who improved enough during ART to remain on active duty, and the DIS group, comprised of the 41 recruits who failed ART and were discharged from the Navy.

A biserial correlation of .32 (p < .05) was obtained between the F4 amplitude measure and the ACT-DIS criterion. Also, results of discriminant analysis (Dixon, 1973) showed that the F4 measure contributed maximally to between-group variance (F = 5.59, df = 1,34, p < .02), with 62 percent of the subjects being correctly classified. When a second measure, P3 amplitude, was added, the number of correctly classified recruits increased to 68 percent (ACT = 56%, DIS = 76%). These results suggested that recruits who were prematurely discharged from recruit basic training tended to show VERP characteristics that distinguished them from those of approximately equal aptitude who successfully completed recruit training.

Sensory Interaction and Reading Ability

Lewis and Froning (1981) examined sensory interaction in a sample of 41 recruits who were divided into two groups based on their reading ability (HIGH vs. LOW). (Reading ability is highly dependent on proper sensory interaction and higher cognitive functioning.)

For this project, the eight electrodes were placed over the subject's frontal (F3, F4), temporal (T3, T4), parietal (P3, P4), and occipital (O1, O2) sites and were referenced to his nose. Visual ERP (VERP), auditory ERP (AERP), and bimodal (visual plus auditory) ERP (BERP) measures were obtained. A subject's sensory interaction was assessed by combining his waveforms in the computer using the expression {BERP - (VERP + AERP)}; the results were called "difference-waves." If the nervous system was linear, the expression (VERP + AERP) would equal the BERP value, and the result would be zero. The interaction could take the form of augmentation (value above zero) or attenuation (value below zero).

Figure 4 shows considerable nonlinearity, as most of the derived waveforms were negative, which suggests attenuation or "inhibition." Greater "inhibition" was seen with the HIGH group than with the LOW group. Such attenuation or "inhibition" is associated with normal cortical function. All sites showed statistically significant differences for the two groups. The greatest group differences, however, were at T4 (t = 20.73, df = 7, p < .01) and were obtained in the second 250 msec portion of the ERP waveform, which suggested that sensory interaction greatly influenced higher-order cognitive functioning. It was suggested that distractability may partially account for the large ERP differences found for the two reading groups.
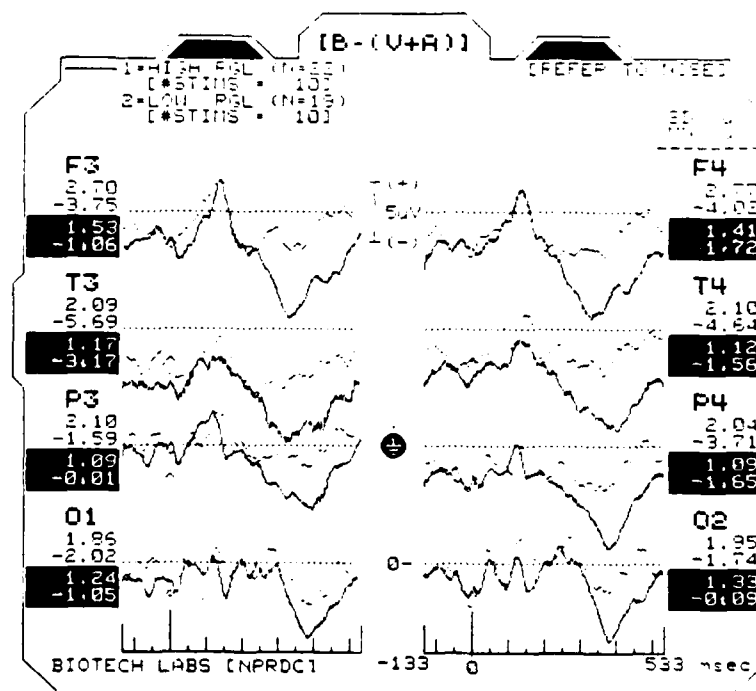

Figure 4.   Difference-wave cortical topography for HIGH and LOW reading groups.

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ERP Measures and Aptitude

The objectives of this project were to determine (1) relationships between visual ERP measures and AFQT scores, and (2) whether ERP data might augment information derived from the paper-and-pencil AFQT for improved personnel classification and performance prediction (Lewis, Rimland, & Callaway, 1979; Naitoh & Lewis, 1981).

Subjects were 206 Caucasian male Navy recruits (basic trainees), who were selected based on the score obtained on the AFQT taken 7 to 15 weeks previously--before they entered the service. Half of the subjects--the LOW group--had AFQT scores ranging between the 20th and 40th centiles (an IQ range from about 87 to 96). (Recruits scoring below the 20th centile are not accepted into basic training.) The other half--the HIGH group--had scores ranging between the 80 and 99 centiles (an IQ range from about 113 to 133). The average age of the subjects was 19 years.

The ERP variables obtained for the HIGH and LOW aptitude groups were factor analyzed, and the resulting factor scores for each subject entered into a discriminant analyses (DA) (Dixon, 1973). Factors relating to latency and several amplitude measures discriminated the two groups. Results were cross-validated ($X^2 = 9.61$, df = 3,98, p < .01) using the sample hold-out procedure. Sixty-four percent of the subjects in the cross-validation sample were correctly classified (LOW = 69%, HIGH = 61%).

Figure 5 is a scatterplot of the ERP data using a trial-to-trial variability measure (Callaway, 1975) vs. P3 and P4 amplitude asymmetry measure {(L-R)/(L+R)}. The HIGH group showed a large amount of homogeneity and a small amount of ERP variability; and the LOW group, a large amount of heterogeneity and ERP variability. Nearly all of the HIGH subjects appeared in the lower left quadrant, while the LOW subjects were scattered more evenly over all four quadrants.
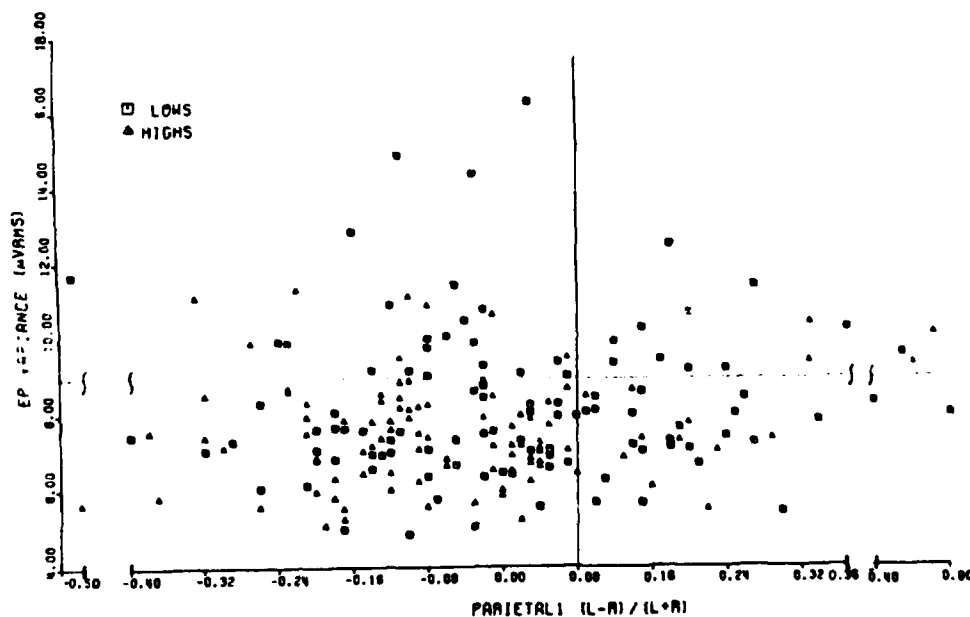

Figure 5.   Scatterplot showing relationship between parietal 1 asymmetry {(L-R)/(L+R)}, ERP variability, and aptitude criterion.

Cluster analysis (CA) using the ERP measures was also performed. Unlike DA, where group membership is predetermined, CA is primarily concerned with finding groups or types of individuals with no preassignment to groupings. Two types or groups of recruits were found, which corresponded to the HIGH and LOW AFQT groupings ($X^2 = 4.48$, $p < .05$). These results suggest that ERP data may augment aptitude measures for personnel assessment and may be sensitive to individual subject differences.

Cognitive Style and Training

In the past, the Navy has experienced manpower skill shortages, and the average ability of recruits has declined. However, more recently, skill shortages have been reduced and the average personnel ability has increased. As a result, the Navy must now adapt and accommodate a wider range of personnel abilities by increasing the effectiveness of its training programs. As one means of achieving this goal, the Navy has implemented computer-managed instruction (CMI). However, CMI is not very adaptive to differences among trainees because it primarily uses self-study materials and requires the students to use self-paced procedures. Techniques are required for better assessing the information-processing styles of individuals so that training can be adapted to their needs. Using the ERP to assess processing styles may be one way to increase training efficiency.

Since brain activity measures derived from computer analyses of ERPs have been found to be related to information-processing styles, this research project attempted to determine the feasibility of using ERPs in the development of adaptive training techniques keyed to the information-processing styles of individual students.

Fifty Caucasian male recruits undergoing basic military training (all right-handed) were given a battery of paper-and-pencil tests designed to assess their cognitive styles, aptitudes, and abilities. Procedures similar to those used by Lewis and Froning (1981) were also used in this project: VERP, AERP, and BERP measures were recorded during the same testing session but not concurrently. Standard deviation microvolt (SDμV) amplitudes were computed for the waveforms at four scalp sites (frontal, temporal, parietal, occipital) over each brain hemisphere. Amplitude asymmetry measures were also computed. Asymmetry was defined as right amplitude minus left amplitude (R-L). The basic ERP data were analyzed to derive measures of sensory interaction {B-(V+A)}. The ERP measures were then related to the paper-and-pencil measures.

Based on results of a cluster analysis of their cognitive style, aptitude, and ability measures, the 50 subjects were divided into two groups: (1) a spatial processing group (N = 18), and (2) a verbal processing group (N = 32). Stepwise discriminant analysis was used to assess ERP differences between the groups. No significant group difference was found for VERP, AERP, or BERP measures, but the sensory interaction data were highly significant on cross-validation. After three steps, the F3 variable discriminated (F = 5.90, df = 3,46, p < .01) and validated ($X^2 = 8.70$, p < .005) the two-group classification. As described in Lewis and Froning (1981), the sensory interaction could take the form of either attenuation (inhibition) or augmentation (excitation). The spatial group showed greater RH attenuation; and the verbal group, greater LH attenuation. The spatial group showed the greatest amplitude asymmetry in response to visual stimuli; and the verbal group, in response to auditory stimuli (see Figure 6).
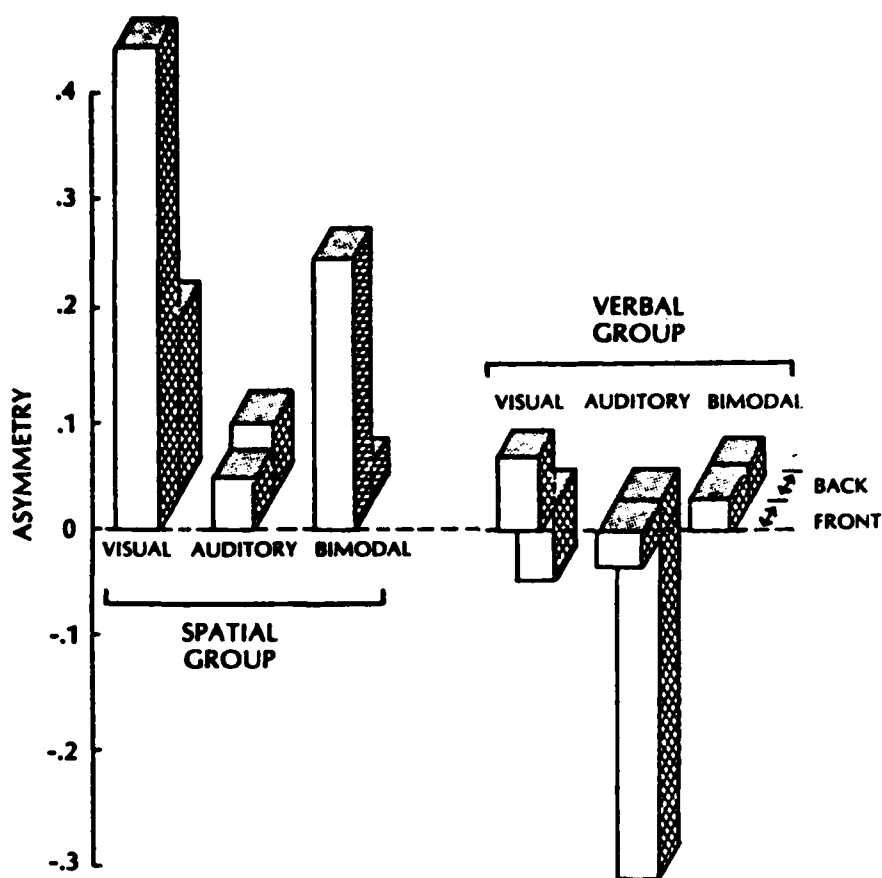
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Figure 6. Front and back lateral asymmetries for the spatial and verbal cognitive style groups.

ERP Measures and Job Performance

Pilot and Radar Intercept Officer (RIO) Performance

Personnel samples described to this point were untrained enlisted recruits with HIGH and LOW ability (i.e., reading and aptitude). The sample in this study was comprised of aviators, who represent the most highly selected and trained group of Navy personnel. Training a single Navy pilot to combat readiness costs in excess of $460,000 (North & Griffin, 1977). Attrition of naval pilot training from 1962 to 1977 averaged about 30 percent (Griffin & Mosko, 1977). North and Griffin (1977), who reviewed the aviation selection literature through 1977, cited 145 studies conducted over nearly 60 years, which represents a large amount of research funds. However, the problem of effectively predicting aviator performance still remains: Only 25 to 40 percent of the variance in performance can be predicted, even though a variety of techniques is available.

One new approach to this problem includes assessing brain processing through direct brain recordings such as the EEG/ERP data. It was felt that pilots may represent a group of individuals who require superior spatial skills, while RIOs may require more analytic

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functioning. Each group, however, must have outstanding ability in both spatial and analytic abilities. Initially, it was hypothesized that important elements of pilot and RIO performance might be categorized as primarily spatial and analytic in nature respectively, and that the pilot group could be discriminated from the RIO group based on scalp-recorded VERP amplitude measures.

During May 1976, NAVPERSRANDCEN's field-portable computer system was used to acquire VERP data from 58 aviators--28 pilots and 30 RIOs--assigned to an F-4 fighter squadron. Roughly half of the pilots and RIOs were instructors, while the other half were students. The three objectives of this research were (1) to determine the feasibility of recording VERP data in a "noisy" operational environment, (2) to determine whether VERP data could measure individual and group differences in the aviator sample, and (3) to relate aviator performance to the VERP amplitude and asymmetry measures (Lewis, 1979; Lewis & Rimland, 1979).

Recording the very small VERP signals in an operational environment proved to be feasible, in spite of the large amount of electrical and acoustical noise. The electrical noise was quieted by using special optical coupling in the VERP amplifier and filter system, together with a special electrical isolation transformer in the power line. The acoustical noise was reduced to an acceptable level by recording inside the van (designed with critical noise-attenuation characteristics) and using white noise for masking.

VERP differences were found between the pilot and RIO groups, particularly at C3 ($F = 6.53$, $df = 1,56$, $p < .02$) and F3 ($F = 5.28$, $df = 2,55$, $p < .05$). These group differences may have been due to training, experience, or job requirements in addition to some selection by paper-and-pencil testing procedures.

It had been hypothesized that HIGH-rated pilots would show greater RH activity than would LOW-rated pilots, and that HIGH-rated RIOs would exhibit greater LH activity than would LOW-rated RIOs. To test these hypotheses, four asymmetry values were computed for the frontal, central, parietal, and occipital sites for both hemispheres and plotted against the performance ratings for the pilot and RIO groups. VERP asymmetry is an index of the differences between the voltages produced at homologous sites on the scalp. The asymmetry value was defined as the RH amplitude minus the LH amplitude (e.g., RH-LH). Interest in related VERP amplitude measures to performance has not been limited to right-minus-left asymmetry differences. Several consistent relationships also have been observed regarding front versus back VERP asymmetry relationships and performance. The asymmetry values for the frontal and central sites were averaged to provide the front measure; and the parietal and occipital asymmetry values, the back. One of the most consistent research findings is that front and back VERP asymmetry group standard deviations (SDs), a measure of dispersion, are related to performance. Similar relationships were also found for the personnel tested in the sonar operator and promotion rate projects to be discussed shortly. One way to assess both individual and group asymmetry differences at the same time is to examine asymmetry SD values.

Each of the pilots and RIOs was placed into HIGH- or LOW-performer groups based on flying proficiency as determined by the squadron operations officer. One finding, which has been consistent over several projects, is illustrated in Figure 7, which shows the SDs plotted for groups (pilots and RIOs), performance ratings (HIGH and LOW), and electrode sites (front and back). (Left-handed and ambidextrous subjects were removed

because hemisphericity may be mixed in these subjects.) The SDs for both the HIGH-rated pilots and HIGH-rated RIOs were about equal at the front and back sites, with the SDs slightly larger for the back than the front sites. The SDs obtained for the LOW-rated groups at the front and back sites were greater than those obtained for the corresponding HIGH-rated groups. Further, the SDs obtained for LOW-rated pilots at the front and back sites were greater than were those obtained for LOW-rated RIOs at these sites. As with the HIGH-rated pilot and RIO groups, the SDs for the LOW-rated pilot and RIO groups were greater for the back than for the front sites. The front-to-back differences were considerably greater for the LOW groups than for the HIGH groups.
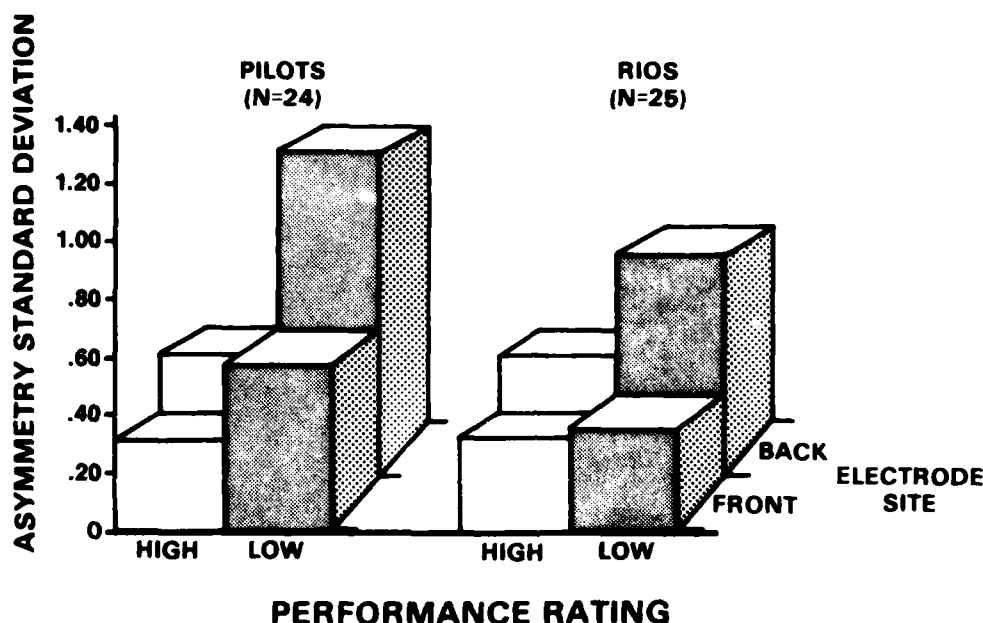

Figure 7.   Asymmetry standard deviations for HIGH- and LOW-rated pilots and RIOs.

The back electrode sites included a primary association area (parietal) and the primary visual reception area (occipital); and the front site, an association area (frontal) and a sensory-motor area (central). The experimental task, which required only observing a blinking light with no muscle activity, was passive.

A final observation in this project dealt with ERP habituation (Lewis, 1979). VERP habituation was assessed by subtracting the ERP amplitudes of the second 50 flashes from the first 50 flashes. The instructors showed VERP habituation (F = 5.98, df = 1,27, p < .02), while the students did not. Mean habituation values plotted separately for aviator instructors and students appear in Figure 8. These habituation data suggested that the instructors may have adapted more quickly to the experimental conditions and were less aroused than were the students.

11

All Instructors (N = 29)
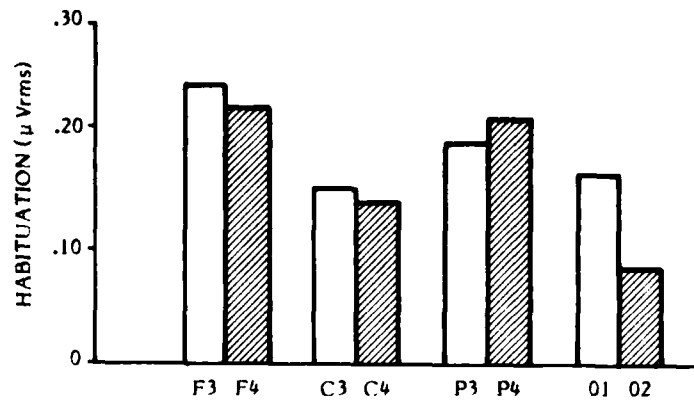
All Students (N = 29)
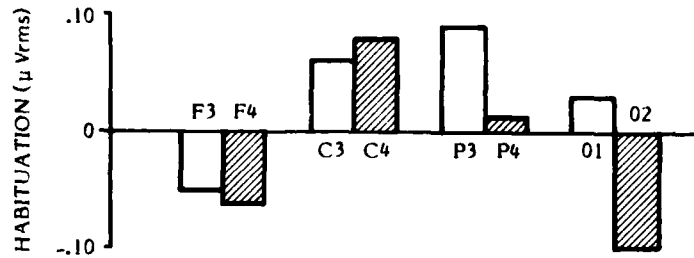
Collapsed Over Sites on Left (LH) and Right (RH) Hemispheres
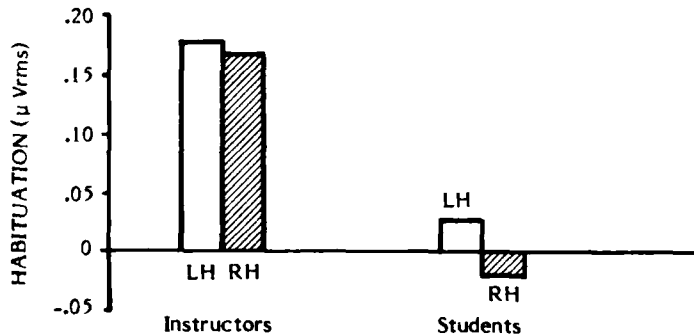
Figure 8. VERP habituation for instructor and student aviators.

Simulator Performance of Sonar Operator Trainees

The operator of today's sophisticated sonar equipment must perform difficult and demanding mental operations requiring quick processing of visual and auditory information and the visualization of moving objects in three-dimensional space. Although conventional paper-and-pencil aptitude tests are reasonably effective in predicting academic performance in sonar school, they are not effective in identifying those who are most likely to perform successfuly as sonar operators.

12

One objective in this research effort was to determine if VERP measures could be related to performance measures to improve the prediction of performance for sonar operators (Lewis, Rimland, & Callaway, 1978; Lewis & Rimland, 1980). The sample consisted of 26 ASW trainees, which were divided into two groups (HIGH (N = 14) and LOW (N = 12)), based on their performance on a sonar simulator. Although the two groups did not differ in their paper-and-pencil aptitude test scores (e.g., AFQT, arithmetic reasoning, mechanical ability) or classroom grade, substantial VERP amplitude (occipital--O1) differences were found (F = 5.87, df = 1,24, p < .02).

Relationships between asymmetry and performance for the ASW trainees were similar to those for aviators (Figure 9). Again, only right-handed subjects (HIGH N = 10, LOW N = 10) were included. The SDs, or asymmetry dispersion measures, were similar from the front and back electrode sites for the HIGH group. Greater front-to-back differences were found for the LOW group than for the HIGH group. Finally, there was less dispersion in both front and back regions for the HIGHs compared with the LOWs.
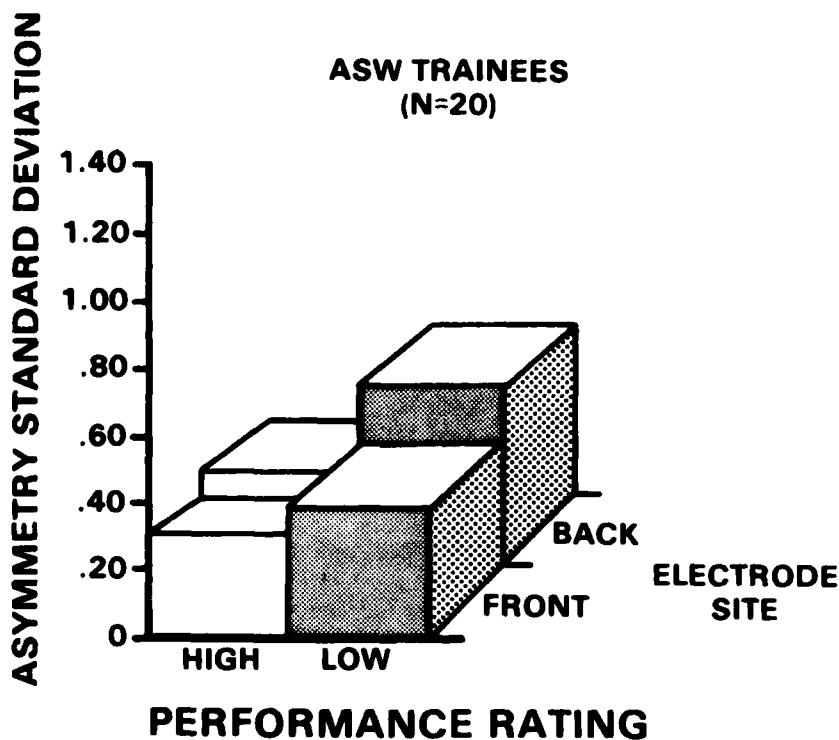

Figure 9.   Asymmetry standard deviations for HIGH- and LOW-rated ASW trainees.

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Enlistee Promotion and Attrition

In this project, follow-up performance records were obtained for enlisted recruits 3 years after recording their initial VERP data. The original ERP data were recorded primarily to compare the VERP amplitude and asymmetry predictors with the traditional paper-and-pencil aptitude and academic predictors used by the Navy. The subjects were 252 members of the sample of 279 recruits used in earlier projects (Lewis et al., 1976, 1977). (Records from 27 recruits of the original sample of 279 could not be located after the 3-year period.) The sample was divided into two groups based on the number of promotions enlistees achieved during the preceding 3 years: The HIGH group (N = 134) had two or more promotions, while the LOW group (N = 118) had less than two promotions. Sixteen VERP amplitude variables (2 series of 50 flashes each for the 8 sites) and 4 aptitude-academic (traditional paper-and-pencil) variables were input to the DA. The four paper-and-pencil test variables included scores from an aptitude test (AFQT), a classification test (General Classification Test), a reading grade level test (Gates-MacGinitie Reading Test), and the highest school grade level completed. Missing paper-and-pencil test data reduced the sample to N = 102 for the HIGH group and N = 70 for the LOW group. Three VERP amplitude measures (P3, C3, O2) were the most effective variables to differentiate (via discriminant analysis) the two groups (F = 3.79, df = 3,168, p < .01) into either the HIGH or LOW promotion group. Classification matrices provide an estimate of how well the discrimination was performed. A total of 58 percent of the cases was correctly classified (X^2 = 6.43, p < .02). The reading grade level and AFQT measures were then entered into the equation, which increased the discrimination of the two groups (F = 3.80, df = 5,166, p < .003). Classification overall was then increased from 58 to 61.5 percent (X^2 = 11.14, p < .001).

Figure 10 shows asymmetry dispersion relationships for the enlistees that are similar to those for the aviator and sonar operator trainee groups. However, unlike those groups, left-handed and ambidextrous subjects were included in Figure 10. The front and back SD measures were lower for the HIGH than for the LOW performance group, a finding similar to that found for the aviator and sonar groups. The HIGH group, however, showed a front-to-back difference, which was not observed for the previous subjects. The back electrode site SD measure was lower than the front for the HIGH group enlistees, while it was slightly greater for the aviators and ASW trainees.

Follow-up attrition data were also obtained for the above sample of enlistees. Enlistees remaining on active duty (N = 143) were compared to those who were discharged from the Navy (N = 108). Of special interest were hemisphere information-processing differences for these two groups. Results of an analysis of variance (ANOVA) showed a large amount of brain asymmetry for the active duty (ACT) group (F = 17.88, df = 1,142, p < .001) but not for the discharge (DIS) group.

Habituation was also assessed by subtracting the VERP amplitude values of the second 50 flash series from those of the first 50 flash series. A significant interaction (hemisphere-by-habituation) was found for the ACT group (F = 4.13, df = 1,142, p < .04), but not for the DIS group. For the ACT group, amplitudes increased from the first series of 50 flashes to the second. Further, their LH amplitudes increased much more than did the RH amplitudes. In contrast, the DIS group showed decreased amplitudes from the first to the second 50 flash series, and their RH vs. LH differences were not as great as for the ACT group. The ERP measures also suggested that the ACT group was more homogeneous than was the DIS group. This finding was analogous to the high performing groups being more homogeneous than the low groups.
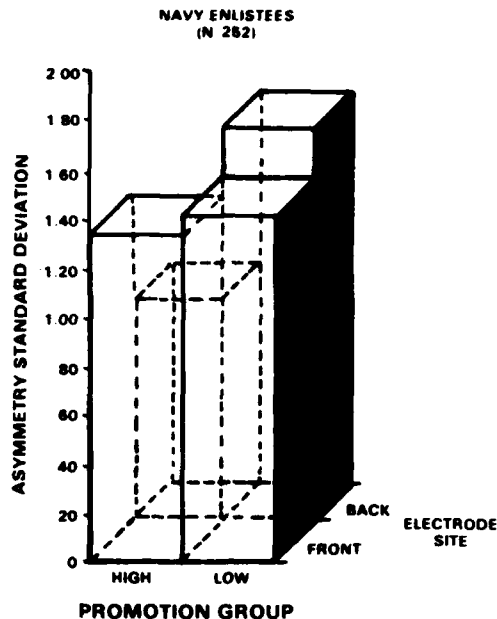
14

Figure 10. Asymmetry standard deviations for HIGH- and LOW-
rated enlistee promotion groups.

Generally, the ACT group showed higher total promotions, fewer desertions, and lower absent-without-leave rates than did the DIS group. These factors are interrelated, as those individuals with high dissertion or absent-without-leave rates are generally also low performers and have a low promotion rate.

ERPs, Color Perception, and Display Systems

Navy use of color-coded visual display systems, which present increased amounts of increasingly complex data, is expected to accelerate in the future.   However, the increased sophistication provided by such systems places greater demands on the personnel required to operate them.   One promising approach toward investigating the effects of color-coding demands on Navy personnel is through the use of ERP records. Recent ERP research relating to the effects of color and color interaction on brain function and perception (White, Kataoka, & Martin, 1977; White, White, & Hintze, 1979, 1982) has found specific ERP components for three basic color processes; presumably, red, green, and blue. It appears that the red process develops most rapidly, followed by the green and then the blue. The White group has also suggested that the components may be related to color processing in different levels of the visual system.   VERP data obtained by the White studies and NAVPERSRANDCEN research (unpublished data) have shown marked individual differences in personnel.   Such results suggest that subtle perceptual characteristics may be assessed through the ERP procedures.

Several laboratories have shown that the presence of pattern elements in visual stimuli produce specific response components in ERP records (Regan, 1972; Desmedt, 1977).   These components vary with the nature of the elements (i.e., linear, curved), density of the elements (i.e., spatial frequency), and the region of the visual field being stimulated (i.e., upper versus lower fields). Sharpness of focus, or the quality of image on the retina, may be assessed through the ERP. Marked individual differences in the ERP to optimal spatial frequencies and binocular summation has importance for assessing Navy personnel performance.

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Testing of subjects at NAVPERSRANDCEN has demonstrated the effects of color and color interaction on brain function and perception. Some of the preliminary findings include:

1. VERP data obtained from red, green, and blue stimuli tends to maximize individual differences to a greater degree than does white stimuli.

2. Presentations of stimuli to each eye separately accentuates individual differences more than does presentation to both eyes simultaneously.

3. Greater ERP amplitude variability was found at the back of the head (visual perception and association area) than at the front of the head where other brain functions are thought to occur.

Figure 11 shows ERP waveforms for two subjects produced by a green-black checkerboard pattern. The eight channels of visual ERP data for subject "A" are overlaid on data for subject "B." Calibration, polarity, and time base information were displayed along with the prestimulus waveforms. Poststimulus waveform amplitude ($SD\mu V$) and mean ($MN\mu V$) values were computed and displayed for each subject's electrode site. The waveforms in the left column were derived from the LH; and those in the right column, from the RH. From top to bottom, the waveforms are from the front to the back of the head at frontal (secondary association area) (F3, F4), temporal (auditory reception area) (T3, T4), parietal (primary association area) (P3, P4), and occipital (visual reception area) (O1, O2) sites. The top two values for each site represent the SD and MN values for subject "A"; and the bottom two values, for subject "B." There are few similarities in the two subjects' ERP records. Those that are present are probably due to the effects of the stimulus.
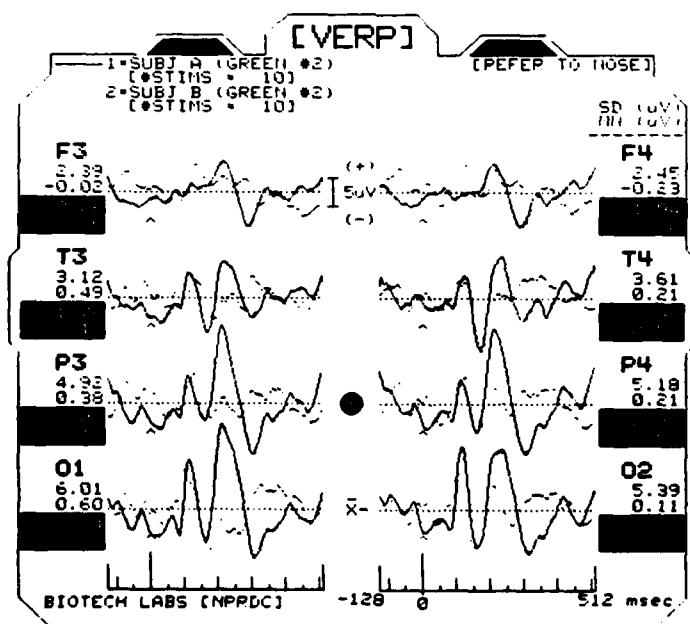

Figure 11. Visual (green stimuli) ERP waveforms for two subjects. (Solid line is for subject A and dotted line is for subject B.)

Figure 12 shows ERP waveforms for a single subject produced by red checkerboard stimuli using the same display format as in Figure 11. The data were obtained about 2 hours apart. A great amount of intrasubject reliability may be seen. Although color stimulation produces high intrasubject reliable waveform records, preliminary data analyses suggest that they may also show maximal intersubject variability.
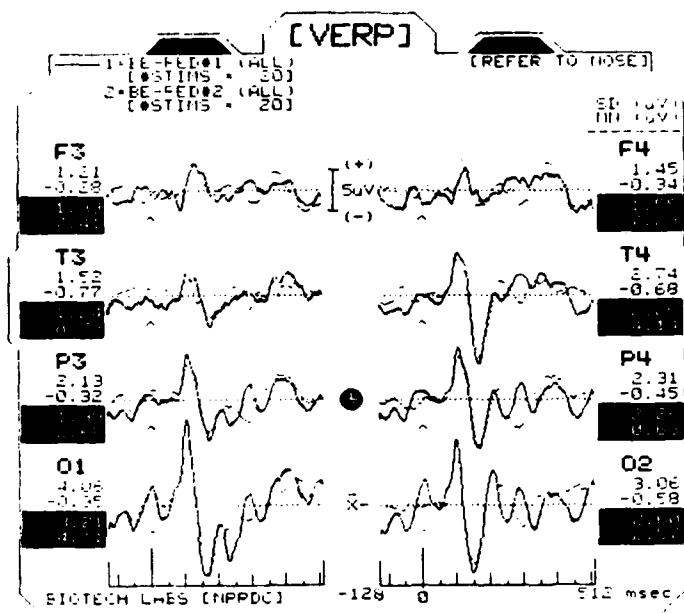

Figure 12. Visual (red stimuli) ERP waveforms recorded about 2
hours apart for a single subject.

Quantitative assessment of these records will require a "template" or pattern recognition and analysis procedure. Currently, cross-correlation and autocorrelation data analytic techniques are being examined at the Center. A color videographic system is being used to assess the qualitative similarities and differences in ERP waveforms. Data are analyzed and displayed over a color video monitor, and either black and white hardcopy or color 35mm slides are made of the displayed data. Since the system can display up to 256 colors simultaneously, the operator can overlay two separate displays of data at one time in separate colors. Where the waveforms do not overlap, the original color (e.g., yellow and green or red and blue) is seen; where the waveforms do overlap, the new combined color (e.g., purple) is seen. Such color-coding makes it very easy to see the ERP waveform areas that are stimulus-dependent (similarities) and the areas that are unique between subjects (differences). Also, similarities and/or differences within a subject may be observed when different stimuli are presented (e.g., visual, auditory).

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FUTURE RESEARCH

This Center ' as established an extensive library of ERP predictor and performance follow-up data using data acquired from both in-house laboratory and operational environments. The lateral asymmetry model of brain processing (e.g., analytic vs. spatial) was used in most of the research reviewed in this report. More recent research findings from the NAVPERSRANDCEN and other laboratories suggest that variability in brain processing may be able to assess and predict performance more effectively than does the asymmetry model. Variability in ERP measures (spatial, over the head, and temporal, over time) parallels cognitive, behavioral, and performance variability.

Research will continue to further evaluate and validate existing and new technologies (e.g., biomagnetic recordings), for improved personnel assessment. Early results suggest that biomagnetic fields from brain (magnetoencephalogram) and heart (magnetocardiogram) may be more sensitive to individual differences than are either ERP or paper-and-pencil tests (Lewis, 1982, 1983). Thus, biomagnetic activity may be a better predictor of on-job performance than are either ERP measures or paper-and-pencil test scores.

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